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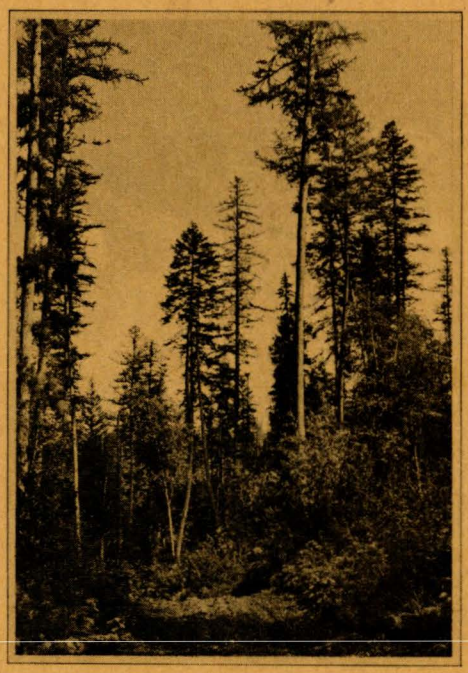
# GROWTH TABLES FOR CUT-OVER LARCH--DOUGLAS-FIR STANDS IN THE UPPER COLUMBIA BASIN

by
Arthur L. Roe



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# GROWTH TABLES FOR CUT-OVER LARCH--DOUGLAS-FIR STANDS IN THE UPPER COLUMBIA BASIN

by

Arthur L. Roe 1/

## INTRODUCTION

Larch--Douglas-fir timber has been cut in various ways in the past. Many stands have been clear-cut of all merchantable timber, leaving a residual stand of cull and undersize trees. Some stands have been cut selectively, taking out only the trees that were suitable for special products. Still others have been cut heavily, leaving only selected seed trees or light shelterwood. Because growth in these residual stands has been highly variable, a study was made in 1947 on a number of residual stands to determine growth responses to different intensities of cutting.

The 1947 study provides a means for predicting growth of trees in cut-over larch--Douglas-fir stands in western Montana. Earlier reports on the study have furnished an analysis of 39 years' growth in a cut-over larch--Douglas-fir stand (1), a vigor classification for larch and Douglas-fir residual trees (2), and a discussion of the response of residual larch and Douglas-fir trees to logging release (3). Analysis of the data now has produced a set of tables for predicting growth of residual trees after logging. These tables are the subject of this report.

These tables will be useful in determining growth of shelterwood, seed trees, and partially-cut stands which retain sufficient vigor to justify leaving as a reserve. Although the tables may be used for predicting growth of selectively cut larch--Douglas-fir stands, the presentation of the growth tables is not necessarily an endorsement of selective cutting. Mature and overmature larch--Douglas-fir stands can best be handled by even-aged management methods such as shelterwood, and clear cutting with seed trees, or possibly patch or strip cutting.

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1/ Kenneth N. Boe, Research Forester, Upper Columbia Research Center, supervised collection of the field data, and A. E. Squillace, Research Forester, Upper Columbia Research Center, assisted in statistical analysis.

## FIELD METHODS

The study was based on field data obtained on 124 one-fifth acre temporary sample plots located in 20 cut-over stands in western Montana. A wide range of reserve stand volumes were sampled. D.b.h., merchantable height, and crown descriptions were collected on all residual trees 7.6 inches d.b.h. and larger on the plots and two increment cores from each were extracted and measured for growth. In addition, all trees 3.6 inches to 7.5 inches were counted on tenth-acre plots, and seedlings (0.5 foot high to 3.5 inches d.b.h.) were counted on five 4-milacre plots within each fifth-acre overwood plot. Only unburned stands which had been logged once were included in the study. Stands which had been disturbed by wood cutting or other activity after logging were not sampled.

## ANALYSIS OF DATA

Growth was analyzed in three categories:

(1) Reserve tree growth -- growth of trees 9.6 inches d.b.h. and larger at the time of logging.

(2) Ingrowth -- volume contribution of trees less than 9.6 inches d.b.h., and therefore with no board-foot volume at the time of logging.

(3) Mortality -- negative growth which reduces net stand growth.

### RESERVE TREE GROWTH

The growth of reserve trees was analyzed by (1) isolating factors associated with growth differences, (2) correlating these factors with relative growth rates, (3) estimating growth from the correlations, and (4) testing these growth estimates by comparison with actual plot growth. The correlations were computed and tested by well-known statistical procedures. Factors studied were: size of trees (diameter and height), period of time since logging, tree vigor, reserve stand density, and precipitation. Estimates based upon the factors studied accounted for an average of 78 percent of the variation.

## INGROWTH

The growth of trees less than 9.6 inches d.b.h. at the time of logging was analyzed separately. Average accumulated diameter growth for each 1-inch class was plotted by 5-year periods since logging and smooth curves were fitted to the data. On the basis of the diameter increases, the periods when the trees first attain merchantable size, and the growth by subsequent 5-year periods were determined. Average mortality was computed and the volumes which had been obtained were reduced to net values.

## MORTALITY

Mortality of reserve trees was analyzed by comparing the number of living trees with the number of dead trees in each diameter class. The dead trees were expressed as a percentage of the total residual trees in the reserve stand. Douglas-fir mortality varied significantly by diameter; it was high in the larger diameters and low in the smaller diameters. Western larch mortality, on the other hand, showed no well-defined trend by diameter. Mortality might correlate with period after logging--being severe immediately following logging and decreasing with time--but no evidence could be found to support that supposition.

## GROWTH TABLES

Tables 1 to 8 present the results of the analysis. Forest managers will find these tables useful for (1) predicting future growth of reserve stands, (2) determining intensity of cutting if partial cutting is proposed, and (3) determining the kind of trees to cut and the kind to leave for best growth. How to use these tables for growth predictions will be explained in the next section. (Tables 1 to 8 follow.)

Table 1.--Western larch. Growth of residual trees, after cutting in mature larch--Douglas-fir stands, average vigor and site quality, western Montana

| D.b.h. in inches at time of logging | Volume at time of logging | Basal area at time of logging | Total growth per tree after an interval of: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Bd. ft. | Sq. ft. | Board feet 1/ | | | | | | | | | |
| 10 | 30 | .545 | 7 | 15 | 25 | 35 | 45 | 55 | 66 | 76 | 85 | 94 |
| 11 | 47 | .660 | 8 | 18 | 31 | 42 | 53 | 64 | 77 | 88 | 98 | 107 |
| 12 | 71 | .785 | 9 | 22 | 36 | 49 | 61 | 74 | 87 | 99 | 110 | 120 |
| 13 | 98 | .922 | 11 | 25 | 40 | 54 | 68 | 82 | 96 | 110 | 121 | 132 |
| 14 | 130 | 1.069 | 12 | 28 | 45 | 61 | 76 | 90 | 106 | 121 | 133 | 145 |
| 15 | 174 | 1.227 | 13 | 31 | 49 | 66 | 83 | 98 | 114 | 130 | 144 | 156 |
| 16 | 221 | 1.396 | 14 | 33 | 53 | 71 | 89 | 105 | 123 | 139 | 154 | 166 |
| 17 | 270 | 1.576 | 16 | 36 | 57 | 77 | 96 | 113 | 132 | 149 | 164 | 177 |
| 18 | 323 | 1.767 | 17 | 38 | 60 | 82 | 101 | 119 | 139 | 157 | 173 | 186 |
| 19 | 375 | 1.969 | 18 | 41 | 64 | 86 | 107 | 126 | 146 | 165 | 182 | 196 |
| 20 | 443 | 2.182 | 19 | 43 | 67 | 91 | 112 | 132 | 153 | 173 | 191 | 205 |
| 21 | 505 | 2.405 | 20 | 45 | 70 | 95 | 117 | 137 | 160 | 180 | 199 | 213 |
| 22 | 570 | 2.640 | 21 | 47 | 73 | 98 | 122 | 142 | 166 | 188 | 206 | 221 |
| 23 | 631 | 2.885 | 23 | 49 | 76 | 102 | 126 | 147 | 172 | 194 | 213 | 229 |
| 24 | 700 | 3.142 | 24 | 51 | 78 | 105 | 130 | 152 | 177 | 200 | 220 | 236 |
| 25 | 778 | 3.409 | 25 | 53 | 80 | 108 | 134 | 156 | 182 | 206 | 226 | 242 |
| 26 | 870 | 3.687 | 26 | 54 | 82 | 111 | 137 | 160 | 186 | 211 | 231 | 248 |
| 27 | 938 | 3.976 | 27 | 55 | 84 | 113 | 140 | 163 | 190 | 216 | 236 | 253 |
| 28 | 1031 | 4.276 | 28 | 57 | 86 | 116 | 143 | 166 | 195 | 220 | 242 | 259 |
| 29 | 1129 | 4.587 | 29 | 58 | 87 | 117 | 146 | 169 | 198 | 224 | 246 | 263 |
| 30 | 1228 | 4.909 | 30 | 59 | 88 | 119 | 148 | 171 | 201 | 228 | 250 | 267 |
| 31 | 1315 | 5.241 | 31 | 60 | 89 | 120 | 150 | 173 | 204 | 231 | 253 | 270 |
| 32 | 1424 | 5.585 | 32 | 61 | 90 | 121 | 151 | 174 | 206 | 234 | 256 | 273 |
| 33 | 1516 | 5.940 | 33 | 61 | 91 | 122 | 152 | 175 | 208 | 236 | 258 | 276 |
| 34 | 1636 | 6.305 | 34 | 62 | 91 | 122 | 153 | 176 | 209 | 238 | 260 | 278 |
| 35 | 1771 | 6.681 | 35 | 62 | 91 | 122 | 153 | 176 | 210 | 240 | 261 | 280 |

1/ Scribner rule.

Table 2.--Douglas-fir. Growth of residual trees after cutting in mature larch--Douglas-fir stands, average vigor and site quality, western Montana

| D.b.h. in inches at time of logging | Volume at time of logging | Basal area at time of logging | Total growth per tree after an interval of: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Bd. ft. | Sq. ft. | Board feet 1/ | | | | | | | | | |
| 10 | 26 | .545 | 6 | 12 | 20 | 30 | 41 | 52 | 68 | 83 | 95 | 114 |
| 11 | 41 | .660 | 8 | 17 | 27 | 40 | 53 | 65 | 82 | 98 | 110 | 130 |
| 12 | 63 | .785 | 9 | 21 | 33 | 48 | 63 | 76 | 95 | 111 | 124 | 144 |
| 13 | 83 | .922 | 11 | 24 | 39 | 56 | 72 | 86 | 104 | 120 | 133 | 154 |
| 14 | 110 | 1.069 | 13 | 28 | 44 | 62 | 80 | 95 | 116 | 132 | 145 | 166 |
| 15 | 149 | 1.227 | 14 | 31 | 48 | 68 | 87 | 102 | 123 | 139 | 153 | 174 |
| 16 | 191 | 1.396 | 16 | 33 | 51 | 72 | 92 | 108 | 129 | 145 | 159 | 180 |
| 17 | 239 | 1.576 | 17 | 35 | 54 | 75 | 95 | 112 | 133 | 149 | 163 | 183 |
| 18 | 280 | 1.767 | 18 | 37 | 56 | 77 | 98 | 115 | 135 | 152 | 165 | 185 |
| 19 | 328 | 1.969 | 20 | 39 | 58 | 78 | 99 | 116 | 136 | 152 | 165 | 184 |
| 20 | 389 | 2.182 | 20 | 40 | 58 | 78 | 99 | 116 | 134 | 151 | 164 | 181 |
| 21 | 436 | 2.405 | 22 | 40 | 58 | 77 | 97 | 115 | 132 | 147 | 160 | 176 |
| 22 | 488 | 2.640 | 22 | 40 | 57 | 75 | 94 | 112 | 127 | 142 | 154 | 169 |
| 23 | 543 | 2.885 | 23 | 40 | 56 | 72 | 89 | 107 | 120 | 136 | 146 | 159 |
| 24 | 609 | 3.142 | 24 | 40 | 54 | 68 | 84 | 101 | 112 | 127 | 137 | 148 |
| 25 | 664 | 3.409 | 24 | 39 | 51 | 62 | 77 | 94 | 102 | 117 | 126 | 134 |
| 26 | 726 | 3.687 | 25 | 38 | 48 | 57 | 69 | 86 | 91 | 106 | 114 | 121 |

1/ Scribner rule.

Table 3.--Adjustment factors for tree vigor and stand density.

| Basal area density class (sq. ft.) | Vigor class by species | | | | | | Weighted average |
|---|---|---|---|---|---|---|---|
| | Western larch | | | Douglas-fir | | | |
| | A | B | C | A | B | C | |
| | Percent | | | | | | Percent |
| 10 | 160 | 95 | 59 | 152 | 95 | 64 | 112 |
| 20 | 148 | 88 | 55 | 141 | 88 | 59 | 104 |
| 30 | 142 | 84 | 53 | 135 | 84 | 57 | 99 |
| 40 | 138 | 82 | 51 | 131 | 82 | 55 | 96 |
| 50 | 135 | 80 | 50 | 128 | 80 | 54 | 94 |
| 60 | 132 | 78 | 49 | 126 | 78 | 53 | 92 |
| 70 | 130 | 77 | 48 | 124 | 77 | 52 | 91 |
| 80 | 128 | 76 | 48 | 122 | 76 | 51 | 90 |
| 90 | 126 | 75 | 47 | 120 | 75 | 50 | 88 |
| 100 | 126 | 75 | 47 | 120 | 75 | 50 | 88 |
| 110 | 124 | 74 | 46 | 118 | 74 | 49 | 87 |
| 120 | 123 | 73 | 45 | 117 | 73 | 49 | 86 |
| 130 | 121 | 72 | 45 | 116 | 72 | 48 | 85 |
| 140 | 120 | 71 | 44 | 114 | 71 | 48 | 84 |
| 150 | 120 | 71 | 44 | 114 | 71 | 48 | 84 |
| 160 | 119 | 70 | 44 | 113 | 70 | 47 | 83 |
| Av. | 143 | 85 | 53 | 136 | 85 | 57 | |

Table 4.--Adjustment factors for mortality by species, average d.b.h., and 5-year periods after logging

| Average d.b.h. of the species (inches) | Interval after logging: 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | | | | |
| | | | | | WESTERN LARCH | | | | | |
| Any | 99 | 97 | 96 | 95 | 93 | 92 | 91 | 89 | 88 | 87 |
| | | | | | DOUGLAS-FIR | | | | | |
| 10 | 99 | 98 | 98 | 97 | 96 | 96 | 95 | 94 | 93 | 92 |
| 12 | 99 | 97 | 96 | 95 | 94 | 92 | 91 | 90 | 88 | 87 |
| 14 | 98 | 96 | 95 | 93 | 91 | 89 | 87 | 86 | 84 | 82 |
| 16 | 98 | 95 | 93 | 91 | 88 | 86 | 84 | 81 | 79 | 77 |
| 18 | 97 | 94 | 91 | 89 | 86 | 83 | 80 | 77 | 74 | 72 |
| 20 | 97 | 93 | 90 | 86 | 83 | 80 | 76 | 73 | 70 | 66 |
| 22 | 96 | 92 | 88 | 84 | 81 | 77 | 73 | 69 | 65 | 61 |
| 24 | 96 | 91 | 87 | 82 | 78 | 73 | 69 | 65 | 60 | 56 |
| 26 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 51 |

Table 5.--Western larch. Volume 1/, Scribner rule, of pole-sized trees following partial cutting in larch--Douglas-fir stands, average site 2/, western Montana

| D.b.h. class at logging (inches) | Volume per tree 3/ after: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Board feet | | | | | | | | | |
| 5 | -- | -- | -- | -- | -- | -- | -- | -- | 38 | 46 |
| 6 | -- | -- | -- | -- | -- | -- | -- | 34 | 41 | 48 |
| 7 | -- | -- | -- | -- | -- | -- | 34 | 39 | 46 | 54 |
| 8 | -- | -- | -- | -- | 32 | 36 | 41 | 48 | 54 | 62 |
| 9 | -- | 31 | 34 | 38 | 42 | 48 | 54 | 60 | 67 | 74 |

1/ Volumes in table reduced by 4% to account for average mortality.
2/ Average site index 83 feet at 100 years.
3/ Trees 9.6 inches d.b.h. and larger.

Table 6.--Douglas-fir. Volume 1/, Scribner rule, of pole-sized trees following partial cutting in larch--Douglas-fir stands, average site 2/, western Montana

| D.b.h. class at logging (inches) | Volume per tree 3/ after: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Board feet | | | | | | | | | |
| 5 | -- | -- | -- | -- | -- | -- | -- | -- | 28 | 33 |
| 6 | -- | -- | -- | -- | -- | -- | 26 | 31 | 38 | 46 |
| 7 | -- | -- | -- | -- | 24 | 30 | 35 | 43 | 53 | 63 |
| 8 | -- | -- | -- | 29 | 35 | 43 | 51 | 60 | 71 | 83 |
| 9 | -- | 29 | 34 | 42 | 50 | 59 | 69 | 80 | 94 | 108 |

1/ Volumes in this table reduced by 7.5% to account for average mortality.
2/ Average site index 83 feet at 100 years.
3/ Trees 9.6 inches d.b.h. and larger.

Table 7.--Engelmann spruce. Volume 1/, Scribner rule, of pole-sized trees following partial cutting in larch--Douglas-fir stands, average site 2/, western Montana

| D.b.h. class at logging (inches) | Volume per tree 3/ after: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Board feet | | | | | | | | | |
| 4 | -- | -- | -- | -- | -- | -- | -- | 25 | 32 | 43 |
| 5 | -- | -- | -- | -- | -- | -- | 23 | 29 | 37 | 48 |
| 6 | -- | -- | -- | -- | -- | 23 | 28 | 35 | 45 | 55 |
| 7 | -- | -- | -- | -- | 24 | 29 | 36 | 44 | 53 | 65 |
| 8 | -- | -- | -- | 27 | 32 | 43 | 48 | 57 | 67 | 77 |
| 9 | -- | 26 | 31 | 37 | 45 | 53 | 62 | 72 | 82 | 93 |

1/ Volumes reduced by 5% to account for estimated average mortality.
2/ Average site index 83 feet in 100 years.
3/ Trees 9.6 inches d.b.h. and larger.

Table 8.--Lodgepole pine. Volume 1/, Scribner rule, of pole-sized trees following partial cutting in larch--Douglas-fir stands, average site 2/, western Montana

| D.b.h. class at logging (inches) | Volume per tree 3/ after: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 yrs. | 10 yrs. | 15 yrs. | 20 yrs. | 25 yrs. | 30 yrs. | 35 yrs. | 40 yrs. | 45 yrs. | 50 yrs. |
| | Board feet | | | | | | | | | |
| 5 | -- | -- | -- | -- | -- | -- | -- | 42 | 51 | 64 |
| 6 | -- | -- | -- | -- | -- | -- | 40 | 48 | 58 | 68 |
| 7 | -- | -- | -- | -- | -- | 40 | 46 | 55 | 64 | 75 |
| 8 | -- | -- | -- | 38 | 42 | 48 | 55 | 64 | 73 | 80 |
| 9 | -- | 38 | 42 | 46 | 51 | 58 | 64 | 73 | 80 | 87 |

1/ Volumes reduced by 10% to account for average mortality. Seven percent is attributable to causes other than insects. Because mortality due to insects was influenced by an epidemic, 3% was assumed to cover average endemic insect loss.

2/ Average site index 83 feet at 100 years.

3/ Trees 9.6 inches d.b.h. and larger.

## HOW TO USE THE GROWTH TABLES

Certain reserve stand statistics are required for predicting future growth:

(1) Number of trees 4 inches d.b.h. and larger, by 1-inch diameter classes and species.

(2) Total basal area of all trees 9.6 inches d.b.h. and larger.

(3) Average diameter of Douglas-fir residual trees upon which to base mortality estimates.

(4) Reserve stand volume in board feet, by species.

(5) Tree vigor (see Appendix table 1 for vigor classification).

A stand table showing the number of trees can be prepared from the timber survey tally if the stand has been cruised, or from the marking record if leave trees were tallied, provided that trees down to 4 inches d.b.h. were measured. Tree vigor may be determined either by classifying all sample trees during the cruise, or by a double sampling process wherein one or two trees on each plot are classified for vigor in addition to the usual measurements taken on all the trees. An adequate vigor sample should contain fifty or more trees.

## COMPUTATION OF RESERVE TREE GROWTH

Growth predictions can be computed from the tables in two different ways, depending upon the method of sampling tree vigor. When all sample trees have been classified by vigor, growth can be computed by a system which we shall call Method One. When tree vigor has been determined by a double sampling procedure, or an independent sample, growth must be determined by a different system. Method Two would give exactly the same results as Method One if applied to data which include 100 percent sampling for tree vigor. However, Method Two is slightly more cumbersome and therefore it is recommended only for the problems where it is the only method that can be employed.

### Method One - All sample trees classified by vigor

Reserve stand data - After the stand has been cruised, the data should be summarized as shown in the first work sheet example, table 9, in the columns headed "number of trees." Because separate growth tables could not be prepared for other tree species which may occur in larch--Douglas-fir types, due to insufficient data, other kinds of trees should be grouped with the larch and Douglas-fir as follows:

Larch -- include lodgepole pine.

Douglas-fir -- include all other species.

Two other columns are provided in table 9 under each species heading for basal area and volume computation. The next step, then, is to determine the basal area of each one-inch diameter class (see tables 1 and 2, third column) and multiply the basal area by the number of trees occurring in each class. The product is entered in the data column opposite each diameter class until the basal area of all trees has been computed and entered as shown in table 9. The individual tree volumes found in column 2 of tables 1 and 2 are then used to determine the volume of residual trees. For example, table 1 shows that the volume of the average 10-inch larch tree is 30 board feet. When that volume is multiplied by the number of 10-inch larch trees shown in the stand table, a product of 204 board feet results (6.80 x 30 = 204). That value is entered in the volume column and the volumes for each diameter class are computed similarly. The average volumes of Douglas-fir residual trees will be found in table 2.

After all the above computations have been completed, the columns in table 9 should be summed and the totals entered in a row across the bottom. Total basal area is obtained by summing the totals of the two basal area columns. The average diameter of Douglas-fir trees is computed by dividing Douglas-fir basal area by the number of Douglas-fir trees per acre, thus $\frac{2.544}{4.08} = 0.624$. The average diameter can then be determined from a basal area table. Thus, 0.624 square feet = 10.7 inches d.b.h. At this point the most important reserve stand statistics, with the exception of vigor, have been determined. They include basal area, reserve stand volume, and average diameter of the Douglas-fir trees. Vigor is evaluated in a later step.

Table 9.--First work sheet for both Methods One and Two.

Reserve stand data

(per acre)

| D.b.h. class (inches) | Western larch | | | Douglas-fir | | |
|---|---|---|---|---|---|---|
| | Trees | Basal area | Volume | Trees | Basal area | Volume |
| | No. | Sq. ft. | Bd. ft. | No. | Sq. ft. | Bd. ft. |
| 10 | 6.80 | 3.706 | 204 | 2.04 | 1.112 | 53 |
| 11 | 6.12 | 4.039 | 288 | 1.36 | 0.898 | 56 |
| 12 | 5.44 | 4.270 | 386 | 0.68 | 0.534 | 43 |
| 13 | 1.36 | 1.254 | 133 | | | |
| 14 | 4.08 | 4.362 | 530 | | | |
| 15 | 2.72 | 3.337 | 473 | | | |
| 16 | 2.72 | 3.797 | 601 | | | |
| 17 | 1.36 | 2.143 | 367 | | | |
| 18 | 1.36 | 2.403 | 439 | | | |
| 19 | 0.68 | 1.339 | 255 | | | |
| 20 | 1.36 | 2.968 | 602 | | | |
| 21 | 0.68 | 1.365 | 343 | | | |
| 22 | 0.68 | 1.795 | 388 | | | |
| 23 | | | | | | |
| 24 | | | | | | |
| 25 | | | | | | |
| Total | 35.36 | 36.778 | 5009 | 4.08 | 2.544 | 152 |

Basal area summary

| | |
|---|---|
| Larch | 36.778 |
| Douglas-fir | 2.544 |
| Total | 39.322 |

Average diameter of Douglas-fir $\frac{2.544}{4.08}$ = .624 = 10.7 inches.

Growth computation - Summarize the number of trees per acre by d.b.h. classes, species, and vigor, as shown in table 10, the second work sheet.

The growth of trees in each diameter class and for the desired period (in this example, 40 years) after logging is read from table 1 for western larch and from table 2 for Douglas-fir. Thus, for example, the gross growth of one 10-inch larch tree is 76 board feet in 40 years. The average growth values are applied to all three vigor classes at this stage of the computation because the adjustments for vigor and density will be computed later. Hence, the growth of 76 board feet will be multiplied by the number of 10-inch trees shown in each vigor class and the products should be entered in the proper data columns in table 10. Thus, 1.36 trees in the 10-inch class, "B" vigor column of the table will have an average growth of 103 board feet (76 x 1.36 = 103).

After average growth has been determined and tabulated on the work sheet for each diameter class by species and vigor, the columns will be summed in a row of totals at the foot of the table. These totals are average unadjusted growth by species and vigor class.

To adjust growth for vigor and density, enter table 3 through the basal area density class which corresponds to the basal area of the stand in question. Because the stand in the example had 39.3 square feet basal area, it falls in the 40-square-foot density class and adjustment factors found in that class will be used. Thus, 138 percent is read as the adjustment factor for "A" vigor larch trees and 82 percent for "B" vigor larch trees, etc. These values are then entered below the growth totals in table 10. Growth is adjusted for tree vigor and stand density by multiplying average growth by the factor. The new totals thus obtained reflect the effect of tree vigor and stand density.

After completing the vigor-density adjustments, the growth of individual vigor classes should be added together for each species, as shown on the second work sheet. The original reserve volume is added to the growth for each species. The new totals are estimates of gross volume of the reserve stand by species 40 years hence. As a final step, mortality adjustment factors are derived from table 4. For western larch, the factor is read below the interval after logging--in the present example, 40 years. Thus, a factor of 89 is obtained for western larch. Diameter need not be considered in western larch because mortality as a percentage of volume was nearly constant regardless of tree size. On the other hand, Douglas-fir mortality increased significantly with increase in diameter. Therefore, the Douglas-fir factor is determined by entering table 4 at

Table 10.--Second work sheet for Method One. Growth computation.

(per acre) Period since logging: (40) years.

Number of trees and growth by species and vigor class

| D.b.h. class (inches) | Western larch | | | | | | Douglas-fir | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A Vigor | | B Vigor | | C Vigor | | A Vigor | | B Vigor | | C Vigor | |
| | No. | B.F. | No. | B.F. | No. | B.F. | No. | B.F. | No. | B.F. | No. | B.F. |
| 10 | | | 1.36 | 103 | 5.44 | 413 | 1.36 | 113 | 0.68 | 56 | | |
| 11 | | | 2.72 | 239 | 3.40 | 299 | 1.36 | 133 | | | | |
| 12 | | | 2.72 | 269 | 2.72 | 269 | 0.68 | 75 | | | | |
| 13 | | | 1.36 | 150 | | | | | | | | |
| 14 | 0.68 | 82 | 2.04 | 247 | 1.36 | 165 | | | | | | |
| 15 | | | 2.04 | 265 | 0.68 | 88 | | | | | | |
| 16 | 0.68 | 94 | 1.36 | 189 | 0.68 | 94 | | | | | | |
| 17 | | | 0.68 | 101 | 0.68 | 101 | | | | | | |
| 18 | 0.68 | 107 | 0.68 | 107 | | | | | | | | |
| 19 | 0.68 | 112 | | | | | | | | | | |
| 20 | 0.68 | 118 | 0.68 | 118 | | | | | | | | |
| 21 | 0.68 | 122 | | | | | | | | | | |
| 22 | 0.68 | 128 | | | | | | | | | | |
| Total | 4.76 | 763 | 15.64 | 1788 | 14.96 | 1429 | 3.40 | 321 | 0.68 | 56 | | |
| Vigor-density adj. factor | x1.38 | | x0.82 | | x0.51 | | x1.31 | | x0.82 | | | |
| Adj. growth | 1053 | | 1466 | | 729 | | 420 | | 46 | | | |

Reserve stand data:
Basal area - 39.3 sq. ft.
Av. d.b.h., D.F. - 10.7 inches
Volume W.L. - 5009 bd. ft.
D.F. - 152 bd. ft.

| | Western larch | Douglas-fir | All species |
|---|---|---|---|
| | 1053 | 420 | |
| | 1466 | 46 | |
| | +729 | + | |
| Total adjusted growth | 3248 | 466 | |
| Original volume | +5009 | +152 | |
| Gross future volume | 8257 | 618 | 7349 |
| Mortality adjustment factor | x0.89 | x 0.92 | +569 |
| Net volume after 40 years | 7349 | 569 | 7918 |

the diameter class corresponding to the average diameter of the Douglas-fir in the reserve stand and reading the value in the time interval column (10.7 inches d.b.h. - 40-year time interval). Thus, in the example, we obtain a mortality factor of 92 after interpolating for the 10.7-inch average diameter. The mortality factors are then entered as shown in table 10. The net future volume is obtained when the gross future volume is multiplied by the mortality factor.

## Method Two - Tree vigor determined by double or independent sampling

Method One is employed when all the sample trees have been classified by vigor. A modified system of computation, Method Two, is necessary when vigor is determined for only part of the sample trees as by double sampling or independent sampling. To illustrate Method Two, assume that the same stand as employed in the previous example had been sampled with 52 plots and that only one Douglas-fir and one larch tree nearest the center of each plot had been classified by vigor.

Reserve stand data - The system of computing reserve stand data is the same for Method Two as for Method One. The principal difference in the two methods lies in the adjustment of growth for density and vigor.

Growth computation - Average growth is determined by summarizing numbers of trees by diameter classes as shown in table 11 and computing the growth by species and diameter classes from tables 1 and 2. The columns should be totaled at the foot of the table to show one average growth figure for each species.

To adjust average growth for vigor and density, the sample trees classified by tree vigor are summarized, as shown in table 12. The field record shown by the dot and dash tally can be made directly on this form. The number of trees in each d.b.h. class are counted and indicated within the small circles. Next the average growth of trees in each diameter class is read from table 1 for larch and table 2 for Douglas-fir. The average growth for a given diameter is multiplied by the number of sample trees contained in that diameter class and the product entered for the diameter class in the proper species column. For example, the average growth of a 14-inch larch is 121 board feet in 40 years. One 14-inch sample larch tree occurred in the A vigor column; therefore, 121 board feet is entered in the data column opposite that d.b.h. class. Three 14-inch "B" vigor larch trees occurred in the sample, thus 121 times three is equal to 363 board feet which is entered in the proper d.b.h. class and data column. This process is continued until average growth is entered for all sample trees. The columns are then summed into a row of totals at the foot of the table.

Table 11.--Second work sheet for Method Two. Growth computations.

(per acre) Period since logging: (40) years

| D.b.h. class (inches) | Western larch | | Douglas-fir | |
|---|---|---|---|---|
| | Trees | Gross growth | Trees | Gross growth |
| | Number | Bd. ft. | Number | Bd. ft. |
| 10 | 6.80 | 517 | 2.04 | 169 |
| 11 | 6.12 | 538 | 1.36 | 133 |
| 12 | 5.44 | 538 | 0.68 | 75 |
| 13 | 1.36 | 150 | | |
| 14 | 4.08 | 494 | | |
| 15 | 2.72 | 354 | | |
| 16 | 2.72 | 378 | | |
| 17 | 1.36 | 203 | | |
| 18 | 1.36 | 214 | | |
| 19 | 0.68 | 112 | | |
| 20 | 1.36 | 235 | | |
| 21 | 0.68 | 122 | | |
| 22 | 0.68 | 128 | | |
| Total | 35.36 | 3983 | 4.08 | 377 |
| Vigor-density adjust. factor | | x 0.816 | | x 1.237 (from table 12, |
| Adjusted growth | | 3250 | | 466 third work |
| Original volume | | +5009 | | +152 sheet) |
| Gross future volume | | 8259 | | 618 |
| Mortality factor | | x 0.89 | | x 0.92 |
| Net volume after 40 years | | 7350 | | 569 |

Reserve stand data:
Basal area - 39.3 sq. ft.
Av. d.b.h., D.F. - 10.9 in.
Volume, W.L. - 5009 bd.ft.
D.F. - 152 " "

Summary of all species

| | |
|---|---|
| Larch | 7350 |
| Douglas-fir | 569 |
| Net volume after 40 years - - - - | 7919 bd. ft. |

Table 12.--Third work sheet for Method Two. Computation of adjustment factor for density and vigor

| D.b.h. class (inches) | Tree vigor | | | | | |
|---|---|---|---|---|---|---|
| | Western larch | | | Douglas-fir | | |
| | A | B | C | A | B | C |
| 10 | | (2) 152 | (4) 608 | (10) 830 | (5) 415 | |
| 11 | | (4) 352 | (5) 440 | (10) 980 | | |
| 12 | | (4) 396 | (4) 396 | (5) 555 | | |
| 13 | | (2) 220 | | | | |
| 14 | (1) 121 | (2) 363 | (2) 242 | | | |
| 15 | | (3) 390 | (1) 130 | | | |
| 16 | (1) 139 | (2) 278 | (1) 139 | | | |
| 17 | | (1) 149 | (1) 149 | | | |
| 18 | (1) 157 | (1) 157 | | | | |
| 19 | (1) 165 | | | | | |
| 20 | (1) 173 | (1) 173 | | | | |
| 21 | (1) 180 | | | | | |
| 22 | (1) 188 | | | | | |
| Total | 1123 | 2630 | 2104 | 2365 | 415 | 0 |
| Percent | 19.2 | 44.9 | 35.9 | 85.1 | 14.9 | - |

| | Western larch | | | Douglas-fir | | |
|---|---|---|---|---|---|---|
| | Pct.dist. | Cor.fac. | Product | Pct.dist. | Cor.fac. | Product |
| A | 19.2 | 138 | 26.5 | 85.1 | 131 | 111.5 |
| B | 44.9 | 82 | 36.8 | 14.9 | 82 | 12.2 |
| C | 35.9 | 51 | 18.3 | | | |
| | 100.0 | | | 100.0 | | |
| Average correction factor (total) | | | 81.6 | | | 123.7 |

The percentage distribution of average growth by vigor classes is determined for each species in table 12. For example, 19.2 percent of the larch growth occurred on "A" vigor trees, 44.8 percent on "B" vigor trees, and 36.0 percent on "C" vigor trees. Vigor-density correction factors are derived from table 3 as described for Method One (39.3 square feet basal area and 40-year time interval). The factors for larch are found to be 138 percent for "A", 82 percent for "B", and 51 percent for "C" vigor trees. When the percent of growth in each vigor class is multiplied by the corresponding adjustment factor (bottom table 12) and the products are summed, an average vigor-density correction factor is obtained for each species. These vigor-density adjustment factors are entered in table 11 below the proper average growth totals. The average growth of each species is then adjusted for vigor-density when multiplied by the adjustment factor.

After adding the original reserve stand volume to the adjusted growth for each species, mortality factors are obtained from table 4 and applied to the gross volumes in table 11 in order to determine future net volume of the reserve stand.

## COMPUTATION OF INGROWTH

So far, the discussion has dealt solely with the growth of the reserve stand--trees 9.6 inches d.b.h. and larger at the time of logging. To complete the growth analysis for the entire stand, ingrowth must be computed.

The computation of ingrowth is started by summarizing the number of trees per acre by diameter classes and species, as shown in table 13. Tables 5, 6, 7, and 8 show the net volumes of larch, Douglas-fir, Engelmann spruce, and lodgepole pine, respectively, by 5-year intervals after logging. For occasional trees of species which are not listed, use the table which seems most appropriate. For example, use the Douglas-fir table (No. 6) for white pine, and the spruce table (No. 7) for alpine fir. Volumes for the desired time interval (in our example, 40 years) and d.b.h. classes when multiplied by the number of trees per acre will indicate the volume per acre of these trees 40 years hence. The volumes should be totaled at the foot of the work sheet (table 13). The totals need not be reduced for mortality because average mortality has been deducted in tables 5, 6, 7, and 8.

Ingrowth is not adjusted for vigor because the effect of that factor has been studied only on reserve trees over 9.6 inches d.b.h. at the time of logging. However, density adjustments should

Table 13.--Work sheet for computation of ingrowth

(per acre) Period since logging: (40) years

| D.b.h. class (inches) | Western larch | | Douglas-fir | | Engelmann spruce | | Lodgepole pine | |
|---|---|---|---|---|---|---|---|---|
| | Trees | Volume | Trees | Volume | Trees | Volume | Trees | Volume |
| | No. | Bd.ft. | No. | Bd.ft. | No. | Bd.ft. | No. | Bd.ft. |
| 4 | 1.36 | 0 | 2.72 | 0 | | | 2.04 | 0 |
| 5 | 0.68 | 0 | 2.04 | 0 | | | 1.36 | 57 |
| 6 | 1.36 | 46 | 1.36 | 42 | | | 0.68 | 33 |
| 7 | 0.68 | 26 | 1.36 | 58 | 1.36 | 60 | | |
| 8 | 0.68 | 33 | 0.68 | 41 | 0.68 | 39 | 0.68 | 44 |
| 9 | 0.68 | 41 | 0.68 | 54 | 0.68 | 49 | | |
| Total | 3.40 | 146 | 4.08 | 195 | 2.72 | 148 | 2.72 | 134 |
| Density correction | | x 0.96 | | x 0.96 | | x 0.96 | | x 0.96 |
| Net ingrowth after 40 years | | 140 | | 187 | | 142 | | 129 |

Summary of all species

| | |
|---|---|
| Larch | 140 |
| Douglas-fir | 187 |
| Engelmann spruce | 142 |
| Lodgepole pine | 129 |
| Net ingrowth after 40 years - - - - - | 598 bd. ft. |

be made on the basis of the reserve stand basal area. Using the reserve stand basal area value from the first work sheet, table 9, as the measure of density--39.322 sq. ft.--find the density correction factor in table 3 in the "weighted average" column at the right-hand side--96 percent. The new values derived by multiplying each of the totals in table 13 by 0.96 are the estimates of future net volume of ingrowth adjusted for stand density.

Total net growth - After the reserve stand volume and ingrowth have been computed, future volume and growth may be summarized by species as follows:

| | Western larch | Douglas-fir | Engelmann spruce | Lodgepole pine | All Species |
|---|---|---|---|---|---|
| Volume of reserve trees 40 years hence - - - | 7349 | 569 | 0 | 0 | 7918 |
| Ingrowth 40 yrs. hence | +140 | +187 | +142 | +129 | +598 |
| Total stand volume 40 years hence - - - | 7489 | 756 | 142 | 129 | 8516 |
| Original reserve vol. | -5009 | -152 | - 0 | - 0 | -5161 |
| Net growth for 40 yrs. | 2480 | 604 | 142 | 129 | 3355 |
| Mean annual ) periodic growth) | 2480/40= 62 bd.ft. | 604/40= 15 bd.ft. | 142/40= 4 bd.ft. | 129/40= 3 bd.ft. | 3355/40= 84 bd.ft. |

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(3) _____
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Appendix Table 1.—Characteristics for classifying the vigor of western larch and Douglas-fir residual trees in larch-fir type in western Montana (2)

| Characters | VIGOR CLASS | | |
|---|---|---|---|
| | A (Good vigor) | B (Fair vigor) | C (Poor vigor) |
| 1. Position of crown | Usually dominant or codominant, occasionally intermediate. | Ordinarily codominant and intermediate, rarely dominant. | Usually intermediate or suppressed, occasionally codominant and rarely dominant |
| 2. Length of the crown | Crown length 40 percent of the total height or longer. Unusually wide crown may be shorter but not less than 30 percent. | Crown length usually from 20 to 40 percent of total height. In narrow crowns greater length may be allowed. | Crown length usually will not exceed 20 percent of total height. In extremely narrow crowns greater length may be allowed, but not to exceed 50 percent. |
| 3. Width of the crown | Crown width average or wider. | Crown usually average width. May be narrow and long or wide and short. | Crown usually narrow or occasionally of average width. |
| 4. Shape of the crown | Tip usually pointed or round, never flat or spike topped. | Tip usually round, occasionally pointed, and rarely flat topped. | Tip usually flat or spike top, rarely rounded. |
| 5. Branching and foliage | Dead branches in the crown rare, branches and foliage moderately dense or better. Branches in upper half of crown usually strongly upturned and no drooping branches. | Occasional dead twigs present, usually no dead branches in the crown. Branches and foliage of moderate density. Occasionally large crowns of extremely open density. Usually the upper branches either upturned or horizontal, with drooping branches in the lower half of crown. | Dead twigs and branches showing through the crown. Often branches drooping to the tip. In western larch 1/ branches short and stout throughout the length of the crown. |
| 6. Bark | Western larch - Bark is usually dark in color and ridged or only slightly scaly with deep fissures between scales. Bark appears rough. These bark characters apply to western larch only. Do not use on Douglas-fir. | Western larch - Bark is usually dark around base of tree, becoming scaly above. Plates not well defined, but bark appears relatively smooth. These bark characters apply to western larch only. Do not use on Douglas-fir. | Western larch 2/ - Bark usually light in color with well-defined large, smooth bark plates and very shallow fissures between plates. Bark appears very smooth. These bark characters apply to western larch only. Do not use on Douglas-fir. |
| | Douglas-fir Bark usually has broad, corky ridges at the base, with light brown new bark prominently exposed in the fissures, becoming uniformly and finely ridged and dark above. The upper quarter or more of the bole usually has smooth or slightly checked light grey bark. | Douglas-fir Bark has corky ridges at the base of the tree, becoming uniformly and finely ridged above. New light brown bark not as prominent as in A vigor and usually extending only part way up the butt log. Dark, rough bark extends at least three quarters or more up the full length of the bole. | Douglas-fir Bark rarely has the light brown new bark exposed in the fissures. Dark bark usually extends to the tip. Frequently the entire bole has dark, finely ridged bark. |
| 7. Disease | No mistletoe infection. | Rarely trees with light mistletoe infection. | Trees with visible indications of moderate to heavy mistletoe infection should be placed in this vigor class. |

1/ Frequently in western larch, short, stout branches near the tip give it the appearance of being pointed. This should not be confused with a pointed growing tip which usually has numerous thin branches and is normally obtusely pointed.

2/ Trees with this type of bark are overmature and usually growing slowly. They should be dropped one class below that in which they would otherwise classify. Thus, if a tree qualifies for A vigor, but possesses the light, smooth bark with well-defined plates and shallow fissures, it should be dropped to the B vigor class.

## LIST OF PREVIOUS PUBLICATIONS IN THIS SERIES

| Station Paper No. | |
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| 1 | °A preliminary study of root diseases in western white pine, by John Ehrlich. Oct. 1939. |
| 2 | °Possibilities of partial cutting in young western white pine, by E. F. Rapraeger. Jan. 1940. |
| 3 | °Blister rust control in the management of western white pine, by Kenneth P. Davis and Virgil D. Moss. June 1940. |
| 4 | Possibilities of wood-pulp production in the northern Rocky Mountain region, by E. F. Rapraeger. Mar. 1941. |
| 5 | Results to date of studies of the durability of native woods treated and untreated, by C. N. Whitney. Rev. Jan. 1946. |
| 6 | Changes in Benewah County forest statistics, by Paul D. Kemp. July 1947. |
| 7 | °A guide for range reseeding on and near the national forests of Montana, by C. Allan Friedrich. Oct. 1947. |
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| 15 | Review of published information on the larch-Douglas fir forest type, by Russell K. LeBarron. Nov. 1948. |
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